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Industrial Utilization of Agricultural Residues

The development of economically sound methods of utilizing agricultural residues or, if you prefer, farm wastes, in industry has constituted a challenge to agriculture and industry for many years. Over the years some progress has been made, but at present somewhat less than two million tons of residues find industrial use.

The magnitude of quantities classified as agricultural residues can best be indicated by comparison with other products. For instance, in 1936 the total annual growth of timber was reported to be equal to 180,000,000 tons of dry material, and 488,830,000 tons of coal and 184,551,000 tons of petroleum were produced. These figures are to be compared with those presented in Table I.

TABLE I.

ANNUAL PRODUCTION IN THE UNITED STATES OF AGRICULTURAL RESIDUES FOR 1931-35 INCLUSIVE [1]

BYPRODUCT	Grain per bushel Pounds	Dry byproduct per pound of grain Pounds	Dry byproduct per bushel of grain Tons	Average production of dry byproduct 1,000 Tons	Estimated quantity of dry byproduct available for industrial use 1,000 Tons
Wheat straw	60	1.9	0.057	38,794	29,000
Rye straw	56	2.5	.070	2,378	1,800
Oat straw	32	1.3	.0208	20,156	0
Barley straw	48	1.2	.0283	5,965	4,474
Flax straw	56	4.0	.112	1,128	1,128
Rice straw	45	1.2	.027	1,089	820
Total straws				69,510	37,222
Corncobs	56	.22	.00616	12,408	1,400
Oat hulls	32	.30	.0048	4,651	150
Rice hulls	45	.20	.0045	182	182
Cottonseed hulls	—	—	——	1,165	583
Peanut hulls	—	—	——	183	92
Total cobs and hulls				18,589	2,407
Corn stover	56	1.2	.0336	63,881	28,500
Cotton stems and pods	—	—	——	17,544	12,281
Bagasse fiber, continental United States	—	—	——	423	423
Bagasse fiber, insular United States	—	—	——	3,276	3,276
Total other by-products				84,924	44,480
Grand total				173,023	84,109

1 Senate Document No. 65 (1939): 76th Congress, 1st Session, Washington, D. C.: p. 51.

In the past this problem has been attacked sporadically by individuals or small groups working in many countries. Too frequently the attempted utilization has been based on the false assumption that these agricultural materials cost practically nothing and that low-cost substitutes could be made from them.

With increasing knowledge, particularly of world resources, it is becoming clear that at some period, perhaps not too far distant, all countries of the world must look to these products of annual growth as the major raw material reserve for the production of fuel, plastics, building materials, many of our organic chemicals, pharmaceuticals, etc. In recognition of the present and future importance of this problem to our national economy, for the first time a group sufficiently large to attack many angles of the problem was organized as the Agricultural Residues Division at the Northern Regional Research Laboratory. The work of this Division is national in its scope. Three main principles are used by this group to guide their research and development work.

1. The improvement of the over-all economics in collection, transportation, and storage of these raw materials.
2. The exploration of the physical and chemical properties of specific residues to determine wherein they may render a service in industrial use not so readily supplied by other raw materials. In other words, determine their superiority in their own right.
3. The development in every process of ways to obtain a money value from each of the three major constituents—cellulose, lignin, and hemicellulose.

The Agricultural Residues Division is comprised of three sections: The Pulp and Paper Section, S. I. Aronovsky in charge; the Plastics and Building Materials Section, R. V. Williamson in charge; and the Industrial Chemical Section, L. E. Schniepp in charge. The names of the first two sections clearly indicate their lines of activities. The Industrial Chemical Section is concerned with a study of furan chemistry, the chemistry of xylose and its derivatives, uses of pentosans, and lignin. The administrative officers of the Division and its sections have backgrounds of successful industrial experience, so that the viewpoint of the group is essentially practical. Using this industrial experience the group has designed and acquired laboratory and pilot plant facilities rarely found assembled under a single management.

Actual laboratory work began early in 1941, and while the war has changed the emphasis of the work, the broad program has been carried on. During this period the Agricultural Residues Division has carried the following projects to completion through a pilot-plant stage: Conversion of butylene glycol to butadiene; development of alpha-cellulose pulps from rice and barley straw for improved gas mask filters; development of Noreseal, recognized as the best substitute for composition cork in sealing beverages and food products; development of Noreplast, a thermosetting resin containing agricultural residues as filler and only 25 percent phenolformaldehyde; and development of ground corncobs and rice hulls as the standard "soft-grit" blasting agent for cleaning Navy aircraft engines.

Large scale laboratory and some pilot-plant work has been directed toward assistance of the strawboard industry, toward development of a small scale process for producing insulation building materials, and toward development of a continuous process for saccharifying agricultural residues. This last process exemplifies in every way the application of the research principles mentioned above. Under a special appropriation for the study of synthetic liquid fuels from agricultural products a semi-works plant is being erected at this Laboratory for the complete evaluation of the saccharification process.

Turning to the problem of industrial fiber utilization, in which the membership of the TAPPI committee is particularly interested, it must be remembered that straw was one of the principal raw materials used for paper manufacture before 1850. Wheat and rice straws, sugarcane bagasse, esparto, bamboo, **Arundo donax,** and the like are still used to manufacture a wide variety of papers in certain parts of the world not abundantly supplied with forests.

In this country and in Great Britain, in spite of all the technological advances in the uses of wood pulp, certain annual plants are preferred and, indeed, required for the manufacture of special paper and board products. For example, wheat straw is preferred for the manufacture of 9-point corrugating box board; flax tow, for cigarette and certain fine papers; esparto, for Bible and similar book papers; linen and cotton rags, for high grade bond and ledger paper; and sugarcane bagasse, for insulating building boards. These preferences are soundly based on the specific properties of the plant fibers which perform a superior service in the finished article.

These specific properties, while they are somewhat general to the fibers of the stems and stalks of annual plants, are often considered by the papermaker to be liabilities rather than assets. The objective of this Division is to use them as assets wherever possible. The high hemicellulose content of the wheat straw contributes to a relatively easily hydrated pulp which produces a stiff corrugating paper. The narrow fiber diameter of esparto and its ability to be easily hydrated without fibrillation make for the wonderful formation, opacity, strength, and printability of Bible paper. The strong bast fiber of the flax makes it suitable for producing cigarette paper meeting rigid specifications. The strength of linen and cotton fibers and their high cellulose content fit them for permanent and strong bond and ledger papers. The long, tough, springy fiber bundles of bagasse make it an outstanding material for the manufacture of low density, strong, and rugged structural insulating board.

By selective cooking and refining of fibrous residues it is possible, on the one hand, to produce fiber bundles for board products of a totally different character than can be produced from wood and, on the other hand, to produce cellulose pulp of fiber diameters much smaller than can be obtained from soft- or hardwoods. These properties have made residues suitable in the past for specialties, a field in which the future growth of the paper industry will find its greatest expansion.

The direction of the pulp and paper studies of the Agricultural Residues Division is, therefore, first, assistance in maintaining the strawboard industry which is the largest single industrial user of residues and, second, a study of the use of these fibers in specialty products ranging from building materials to the finest papers. This second phase of research involves much fundamental and background work in the knowledge of fiber properties and fiber behavior. Pulping methods and techniques in this field are obsolete as compared with advances made in pulping wood. Pulping studies will be directed to capitalizing the high hemicellulose content of straws and other residues which will bring yields more in line with those from woods. Chemical recovery will be an important consideration in pulping processes. New pulping techniques, such as nitric acid pulping, butanol, or other organic pulping, will receive attention.

It should be clear that the work of the Agricultural Residues Division is directed not toward replacing wood pulps, but rather toward supplementing them, or even better toward the development of new products for which wood pulps may not be so well suited.

This review was prepared by E. C. Lathrop, Head, Agricultural Residues Division, Northern Regional Research Laboratory, Peoria, Ill. and was presented at the meeting sponsored by the Fibrous Agricultural Residues Committee of the Technical Association of the Pulp and Paper Industry held at Peoria on April 25-26, 1945.